PLASTER MOLDS OCCURRING IN BEDS OF THE CULTIVATED MUSHROOM[1]

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INTRODUCTION

Among the numerous fungi that may be found in the compost of mushroom beds in the United States, two are often conspicuous. One develops over the surface of the manure in patches that are white in the early stages of growth, turning cinnamon-brown after a few days. The other fungus grows deep into the beds, forming a white powdery mass that may become a pinkish gray but never brown. These molds are responsible for considerable economic loss, and most experienced growers are familiar with their gross appearance. A great deal of confusion, however, has arisen from the use of different common names by different growers and from the fact that the relation of these fungi to described species has not been clearly defined. In an attempt to clear up this confusion the writers have isolated and critically examined cultures of both fungi from several localities. The present paper reports data on their distribution, variability, and probable relation to species described in foreign countries. In the following discussion the subsurface mold will be designated "white plaster mold" and the surface mold "brown plaster mold".

WHITE PLASTER MOLD

White plaster mold is the more injurious of the two fungi under consideration. It penetrates deeply into the beds and gives the compost the appearance of having been dusted with flour. It greatly retards or completely inhibits the growth of mushroom spawn, so that its presence in the beds frequently results in the total failure of the crop.

The occurrence of plaster mold in the United States was first brought to the attention of the Department of Agriculture in 1897, when material was received from San Rafael, Calif., with the information that the spawn had made a certain amount of progress but had suddenly been checked. The second report of the occurrence of this disease in the United States was received in 1920, this report also coming from California. Two years later the same grower reported that a loss of over $100,000 had been suffered by California growers, and his personal loss was estimated at from $20,000 to

[1] Received for publication Feb. 23, 1933; issued July, 1933.
[2] Acknowledgment is made of a culture of white plaster mold from Dr. Louise Dosdall, University of Minnesota, and of two cultures from Dr. W. M. Ware, of England, in 1930.

$30,000 during a period of 4 years. Since then the writers have observed similar failures and have identified and isolated the fungus from collections made in Pennsylvania, Minnesota, California, Idaho, Illinois, and New York.

White plaster mold is also a serious pest in France, Italy, and England. Detailed accounts of extreme losses from this fungus are given by Costantin and Matruchot (*5*) [3] for France, and Cuboni and Megliola (*6*) for Italy. Recently Ware (*14, p. 19–20*) in England also mentioned it as a competitive invader in mushroom beds.

IDENTITY

The various collections of white plaster mold made by the writers in four different States and from many different beds agree very well with the original description of *Monilia fimicola* by Costantin and Matruchot (*5, p. 292*), who found it causing a disease of mushroom spawn in 1894. Because of the plasterlike character of this fungus they referred to it as "le plâtre".[4] Their description is as follows:

> Mycelium colorless, septate, little branched, 2μ–5μ in diameter. In pure culture the sporiferous filaments are first in groups of 4 or 5, and the groups are separated from each other by a long portion of sterile mycelium.

The development is described as follows:

> The sporiferous filament is at first simple and fruits at its extremity, soon branching irregularly, each branch producing a chain of many spores. The fruiting filaments vary from 50μ to 100μ, are cylindrical at the base and the same size as the mycelium, diminishing gradually toward the extremity.

Unfortunately, in this description the size and shape of the spores were omitted. However, the shape of the spores and their size in relation to the mycelium are shown clearly in the drawings (*5, pl. 13, figs. 9–13*). In 1906 Saccardo (*11, p. 503*) described the spores as elliptical with obtuse ends and 6.5μ–8μ by 4.5μ–5.3μ in size. The inference is that these measurements were estimated from the magnification of the drawings. They agree with the measurements of spores in the writers' cultures. Figure 1 shows spores from a culture of *Monilia fimicola*. The U-shaped dichotomous branching of the sporophores as shown in the drawings of Costantin and Matruchot was also found to be quite characteristic of the writers' cultures. Figure 2 shows U-shaped branching of the mycelium. Figure 3 is from a culture of *M. fimicola* showing mycelium and spores.

In 1903 the Italian investigators Cuboni and Megliola (*6*) published an account of this disease in Italy. Their observations led them to the conclusion that the Italian fungus was identical with *Monilia fimicola;* but because the mycelium was limited to the substrata, and because the spores were extremely small, they referred it to the genus *Oospora*, designating it *Oospora fimicola* (Cost. and Matr.) Cub. and Megl. The two descriptions of this fungus by the French and the Italian authors, respectively, are very similar, the main difference being in the shape of the spores. Cuboni and Megliola describe them as globose, whereas those in the drawings of Costantin and Matruchot (*5*) are ovoid. In the course of this study the writers

[3] Reference is made by number (italic) to Literature Cited, p. 1097.

[4] It should be noted here that Costantin (*4*) first applied the name "plâtre" to a very different fungus, *Verticilliopsis infestans*, but later referred to *Verticilliopsis* as the "faux plâtre" of the gardeners.

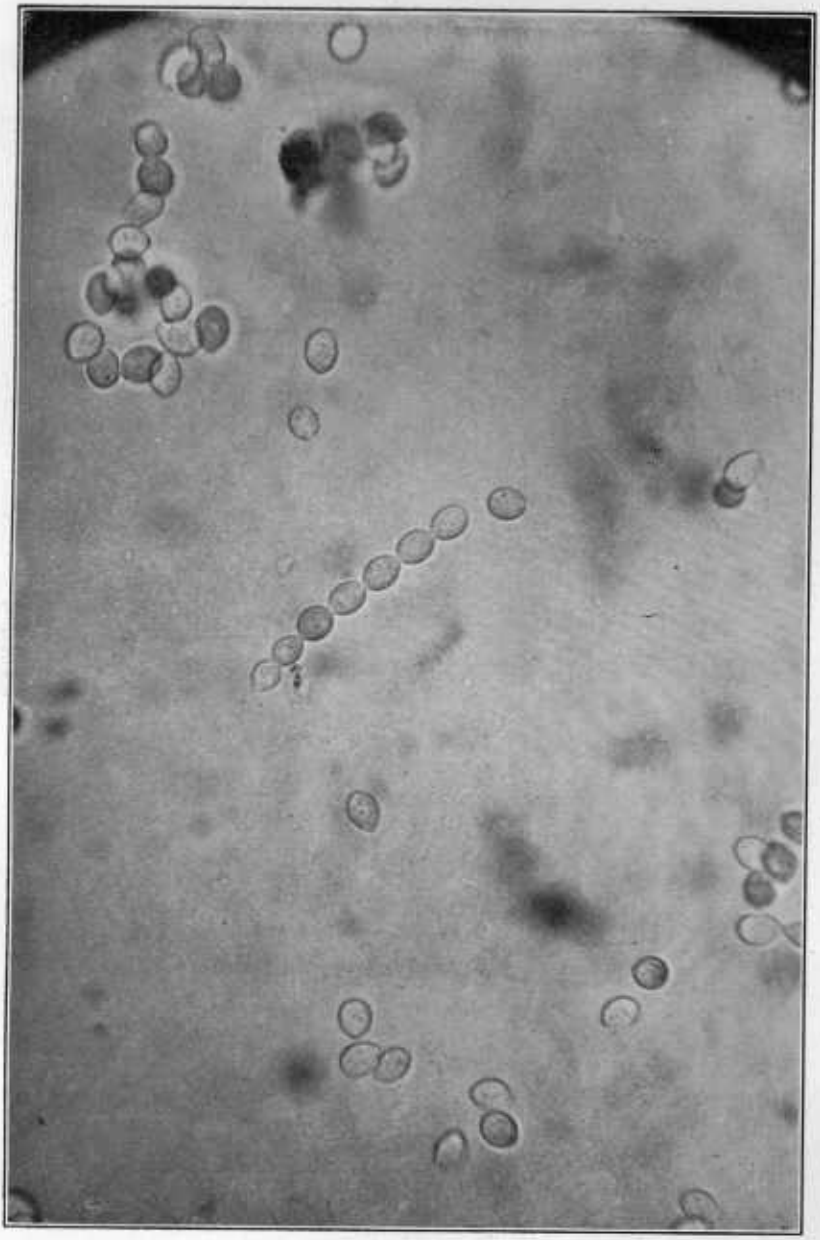

FIGURE 1.—Spores from culture of *Monilia fimicola*. × 800

examined a specimen from Cuboni distributed by D. Saccardo[5] and found only a few globose spores, the majority being oval. It is noteworthy in this connection that the spores in the Cuboni specimen also correspond in size and shape with the spores from the writers' cultures. Whether this species is to be considered as belonging to the genus Monilia or to the genus Oospora is largely a matter of interpretation. Since sterile hyphae are plentiful on ordinary media, the writers prefer the older name *Monilia fimicola* Cost. and Matr.

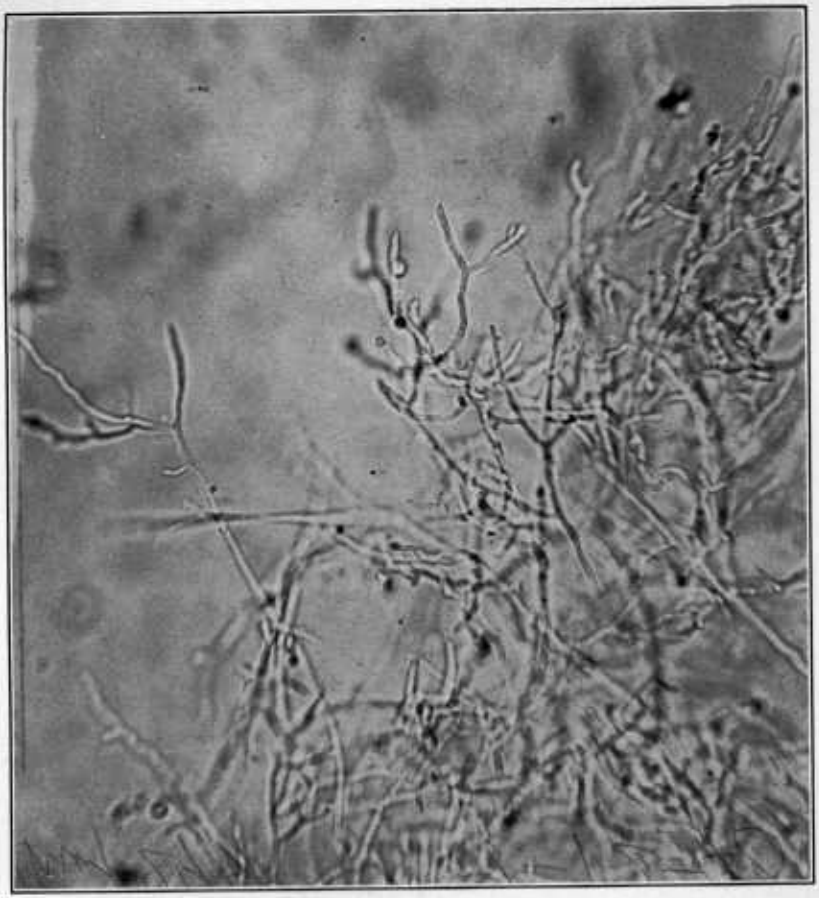

FIGURE 2.—U-shaped branching of the mycelium of *Monilia fimicola*. × 380

In 1930 W. M. Ware sent the writers two cultures of *Monilia fimicola* which he had collected in England in 1929. One was isolated from a sample of dung from a mushroom bed at Bradford-on-Avon, Wiltshire, and the other was from a fragment of brick spawn at Lewes, Sussex. Both of these cultures were similar in shape and size of spores and general cultural characters to those isolated by the writers in the United States.

[5] Mycotheca italica Mucedinaceae, 1572, *Oospora fimicola* (Cost. et Matr.) Cub. et Megliola, Albano (Roma)—in palea putri et in fimo equino—valde noxia mycelio Agarici campestris—November 1903, Prof. G. Cuboni.

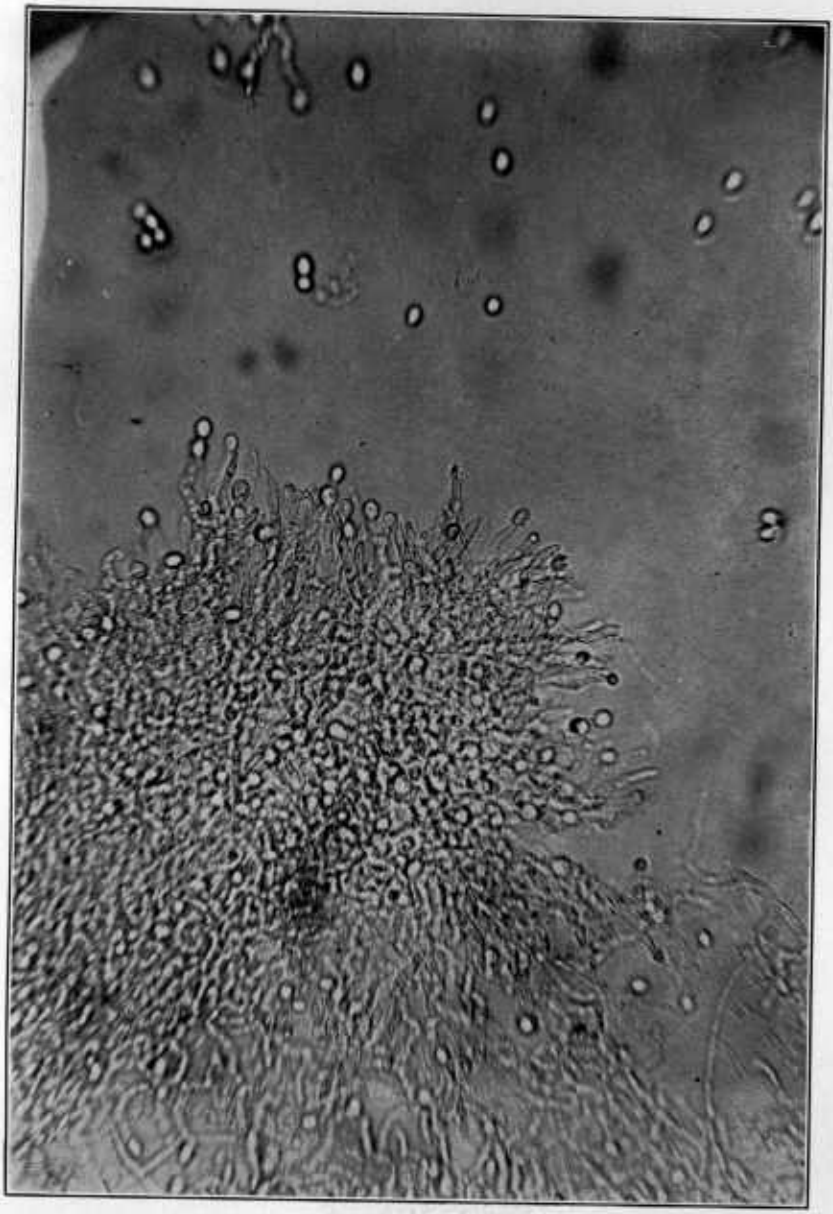

FIGURE 3.—Culture of *Monilia fimicola* showing mycelium and spores. × 380

PHYSIOLOGIC SPECIALIZATION AND MUTATION

Despite the rather constant morphology of spores and sporophores in cultures isolated from different collections of *Monilia fimicola*, there were often distinct differences in the cultural characters of strains originating from different collections when grown under identical conditions. In some cases the pale pinkish-buff color typical of the fungus mat and the coloring of the medium were entirely absent. These differences were especially noticeable when the cultures were grown in triplicate Erlenmeyer flasks on potato-dextrose agar. In the writers' opinion the differences were sufficient in four cases to indicate distinct physiologic forms, as this term is used by Stakman and his coworkers (*2*, *12*, *13*).

It is also of interest to note that sectors arose in several of the cultures when grown in flasks. These sectors were oftentimes quite

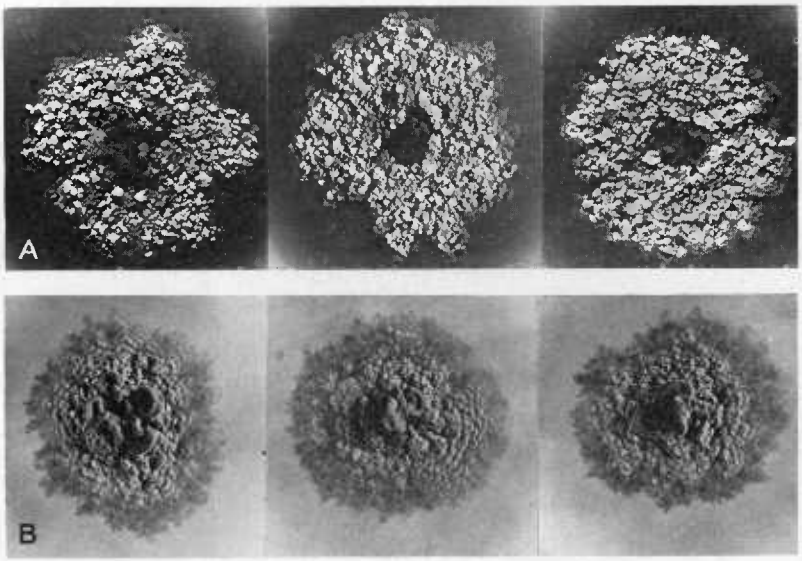

FIGURE 4.—Physiologic forms and sectoring in *Monilia fimicola*: A, Cultures of strain from California; B, from Idaho, middle culture of latter showing sector emerging. × ⅜.

distinct from the parent cultures. For example, some of the sectors were ivory-yellow and waxy, while the fungus mat of the parent cultures was pale pinkish-buff and diffuse powdery. Subcultures from these sectors had the same general cultural characters as the sectors. In monosporous cultures sectors arose which were as distinct as those appearing in mass cultures. The writers interpret these sectors as arising from mutations, as this term is used by Stakman, Christensen, et al. (*2*, *12*, *13*). The cultures shown in figure 4 are triplicate subcultures from monosporous cultures of two strains of *Monilia fimicola* grown under identical conditions on Filco potato-dextrose agar in 250-cc Erlenmeyer flasks. The strain shown in the upper row was collected in a mushroom bed near San Francisco, Calif., and that shown in the lower row was collected near Boise, Idaho. There is an evident difference in the appearance of the

fungus mat and the coloring of the medium produced by the two strains. A sector may be seen emerging from the central culture of the Idaho strain.

BROWN PLASTER MOLD

Brown plaster mold is popularly so called because of the cinnamon-brown color which characterizes it at maturity. It has been found in varying amounts in almost all commercial mushroom houses visited by the writers in the eastern part of the United States. It has been known to commercial mushroom growers for some years and was first observed by the senior writer in Pennsylvania and New York in 1923. It is typically a surface grower both when it occurs in nature and when grown artificially on culture media. Over the surface of the beds it forms patches that are usually from 6 to 15 inches in diameter. These patches, at first white and plasterlike, soon change to tan and finally to cinnamon-brown, becoming less conspicuous as they mature. In most cases similar patches may be observed under the side boards. Sometimes several patches will coalesce to form a continuous coating over the surface of the compost. When the casing soil is applied to infested beds the fungus reappears after a short delay over the surface of the casing soil. Mushroom mycelium seems to experience considerable difficulty in penetrating these spots. As a result the production of sporophores is retarded within infested areas, and the yield is noticeably reduced.

IDENTITY

If the white patches over the surface of the beds are examined with a hand lens they are seen to consist of numerous spherical bodies. Occasionally these bodies are elongated by the fusion of two. In a few instances there may be a prolongation suggestive of a neck. In size they range from 80μ to 110μ in diameter. In the early stages they consist of mostly hexagonal isodiametric cells. As they develop, the cells of the outer layer become somewhat flattened and pigmented.

Hein (*8*, *9*) isolated cultures of this fungus and found it ideal material for study of concentric rings in culture and the production of tetrakaidecahedron in pseudoparenchyma. He considers the spherical bodies sclerotia and gives excellent illustrations of their structure and cultural characters but does not attempt to identify the fungus with any known species.

The authors have found the so-called sclerotia collected from mushroom beds to be practically identical with those in a specimen of *Myriococcum praecox*[6] in the Mycological Collections of the Bureau of Plant Industry. Two other specimens of this fungus were also examined, one in the Mycological Collections[7] of the Bureau of Plant Industry and a second specimen from Denmark, determined by Rostrup. These two collections also correspond with the writers' collections. The species was described by Fries (*7*) in 1823 as the type of Myriococcum, a poorly described and little understood fungus.

The systematic position of Myriococcum is very uncertain, and by most modern authorities Myriococcum is placed among genera dubia in the Perisporiales. It was placed by Fries in the class Gasteromy-

[6] FRIES, E. SCLEROMYCETI SUECIAE, Dec. 7, No. 70.
[7] Collected by A. B. Langlois, No. 914, on decaying wood in Louisiana.

cetes, order Angiogastres, suborder Nidulariaceae, and by Corda (*3*) in the family Physarei, section Eurotiaceae. In 1842 Corda (*3*) published the results of his observations and expressed doubt as to whether or not the interior of the fungus body was chambered or hollow, but was inclined to the latter belief, as no fragment of an interior wall could be found. He stated that the spore mass filled the interior completely, and he described the spores as elongate, many sided, nearly wedge-shaped, white, and transparent. From numerous examinations it would appear that what have been called spores are in reality the inner cells which are less compressed and therefore not as uniformly hexagonal as the outer cells.

Attention may also be called to the close resemblance of *Sclerotium eurotioides* Lib. to the brown plaster mold. *S. eurotioides* was described in 1832, the description on the specimen label reading as follows: "Congestum tectum, minutissimum, globosum, leve, stramineum, demum fulvum, 100μ diameter; villo mucido demum evanescenti insidens."[8] A Libert specimen of this fungus in the Mycological Collections of the Bureau of Plant Industry appears identical in size and structure. The color is slightly lighter in the Libert material, but the difference is slight and may be due to age or the difference in the substratum. The writers are inclined to consider the spherical bodies either as abortive perithecia or the bulbils of a Hymenomycete.

DISCUSSION

Evidence has been presented which shows that the white and brown plaster molds are distinct and referable, respectively, to *Monilia fimicola* Cos. and Matr., and *Myriococcum praecox* Fries. Comparative studies of the cultural characters of eight different collections of *Monilia fimicola* from different localities in the United States and England bring out the fact that biotypes exist in this species which sometimes have quite different cultural characters under identical conditions and presumably differ likewise in their general physiology. Thus caution is necessary in generalizing from physiological data obtained for this species, such as thermal death curves, in relation to control practice. In one collection an unidentified *Monilia* was isolated which has pointed spores averaging 6μ–6.5μ by 3μ–3.5μ, but since *M. fimicola* was isolated from the same collection the significance of the unidentified fungus is problematic.

The brown plaster mold (*Myriococcum praecox*) has never been described in connection with European mushroom culture, and it is evident that the white plaster mold (*Monilia fimicola*) is identical with "le plâtre" of France and the "plaster mould" of England. For this reason the terms "brown plaster mold" and "white plaster mold" are preferred by the writers to the terms "plaster mold" (for the Myriococcum) and "flour mold" (for the Monilia), which are sometimes used (*1*). These terms are perhaps as descriptive as white and brown plaster mold under domestic conditions, but they may lead to confusion when comparisons are made between domestic and foreign conditions.

To avoid confusion of the plaster molds with other species of *Monilia* encountered in connection with mushroom culture, mention should be made of still another species of *Monilia*, one belonging to

[8] LIBERT, M. A. PLANTAE CRYPTOGAMICAE ARDUENNAE, Cent. 2 (1832), No. 138.

the *M. sitophila* group. This species has come to the attention of the writers intermittently over a long period of years as a contaminant in the manufacture of spawn. A recent French paper by Moruzi (*10*) dealing with this fungus is entitled "Sur une Maladie du Champignon de Couche Causée par un Monilia." This title would seem to be rather misleading, as the fungus was only encountered in the manufacture of spawn. Furthermore, Moruzi's paper deals with the cytology of the organism rather than with its role as an invader in mushroom beds. The writers' observations lead them to believe that *M. sitophila* cannot successfully compete with the microbial flora in well-composted manure and that it is seldom, if ever, found on the beds with the plaster molds.

SUMMARY

Serious losses are suffered by mushroom growers in the United States through the presence in mushroom beds of certain fungi popularly known as plaster molds. The most dangerous of these fungi is the white plaster mold found to be identical with "le plâtre" of France and described by Costantin and Matruchot in 1894 as *Monilia fimicola*. This species has been collected in California, Idaho, Illinois, Minnesota, Pennsylvania, and New York; and while the collections are morphologically identical, there are physiologic forms in the species, and sectors frequently appear in flask cultures. *M. fimicola* is also recognized as a serious menace to successful mushroom growing in England and Italy.

The second fungus, brown plaster mold, although commonly present in mushroom beds in the United States, has not been described in connection with mushroom culture in Europe. It is here recognized as identical with *Myriococcum praecox*, a fungus described by Fries in 1823.

Attention is also called to the occurrence of *Monilia sitophila*, which should not be confused with the plaster molds. It often appears as a troublesome contaminant in the manufacture of spawn both in the United States and Europe, but is seldom, if ever, found in composted manure with the plaster molds.

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